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Soil surface microbial communities control spectral response of desert regions

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About one third of dryland soils are covered by biological soil crusts (biocrusts), which are complex communities of cyanobacteria, algae, lichens and mosses in intimate association with the soil surface and heterotrophic microorganisms. These communities are considered as one of the main photoautotrophic communities and are being discussed as relevant C pools of drylands. They also fix atmospheric nitrogen and protect the soil surface from erosive agents, improving soil quality and fertility. In addition to these well-known effects, detailed spectral analyses have demonstrated that biocrusts modify the soil surface reflectance, with two main absorption features at ∼500 and ∼680 nm, which are related to the presence of carotenoids and chlorophyll a. They also have been shown to mostly decrease overall surface re[U+FB02]ectance, and, similar to vegetation, changes in greenness or water status in biocrusts modify their spectral response. These specific spectral traits facilitate mapping of biocrusts by means of remote sensing techniques. Despite all the spectral effects and the extended coverage of biocrusts in drylands, their presence is only rarely considered during remote sensing studies and spectral index assessment in these regions.
Thus, in the current study we i) analyzed the effects of biocrust cover and water status on the spectral response of typical heterogeneous dryland surfaces, and ii) quantified how these effects modify the value of some of the most widely used broad-band spectral indices, like the NDVI and EVI. iii) We then applied an existing biocrust classification index in a semiarid area in the Succulent Karoo, South Africa, to demonstrate their relevance in terms of coverage and biomass. In a final step, we iv) used these maps to identify LANDSAT pixels dominated by biocrusts and in these we evaluated the effects of biocrusts on short-term alterations of NDVI values in response to water pulses.
As expected, biocrust cover caused an overall decrease in surface reflectance with absorption features at ∼500 and ∼680 nm. Upon wetting, they immediately turned dark, thus increasing the observed features. Consequently, biocrusts caused an increase of NDVI and EVI values and wetting also significantly affected these values. We observed an NDVI value of ∼0.2 for a pixel fully covered by biocrusts under dry conditions, which may reach values close to 0.4 after wetting, and the latter is also a typical value of dryland vegetation. In the study area of the Succulent Karoo, where biocrusts cover about one third of the landscape, overall biomass values of ∼480 g ha $^{-1}$ of chlorophyll a + b were reached. The spectral effects of biocrusts in this region were observed to control the annual dynamics of vegetation indices analyzed at a coarser scale, whereas scarce vegetation played only a minor role. Our results illustrate the impact of biocrusts on the spectral response of dryland surfaces, emphasizing the need to consider their presence in studies aimed at analyzing dryland water status, phenology and productivity.